FEEDING AND GROWTH OF GOLDEN PERCH LARVAE AND FRY (*MACQUARIA AMBIGUA* RICHARDSON)

by P. T. ARUMUGAM & M. C. GEDDES*

Summary

ARUMUGAM, P. T. & GEDDES, M. C. (1987) Feeding and growth of golden perch larvae and fry (*Macquaria ambigua* Richardson). *Trans. R. Soc. S. Aust.* 111(1), 59-65, 29 May, 1987.

Golden perch larvae were stocked into an earthen pond and grew exponentially from a mean standard length 4.5 mm (dry weight 0.16 mg) to a mean of 31 mm (165 mg) in 46 days from 12 November until 28 December, 1984. The growth coefficients were 0.04 mm mm^{-1} day^{-1} for length and 0.15 mg mg^{-1} day^{-1} for weight. The mouth gape was related to length. At first feed the type and size of prey was restricted by poor swimming and pursuit abilities and small mouth gape. Larvae and fry greater than 10 mm standard length were able to pursue a wide range of zooplankters but feeding was limited by mouth gape. The daily food consumption of larvae and fry increased from 33 to 5600 µg dry weight per day. Because of the relatively small size of golden perch larvae at first feed, survival is dependent upon a high density of appropriate sized zooplankters.

KEY WORDS: Fish, larvae, fry, *Macquaria ambigua*, feeding, growth, mouth gape.

Introduction

The golden perch (*Macquaria ambigua* Richardson) belongs to the Percichthyidae, a group of fishes which includes both freshwater and marine representatives. *M. ambigua* occurs throughout the Murray-Darling system except at higher altitudes, in the Lake Eyre and Bulloo-Bancannia drainage systems and the Dawson-Fitzroy River system in eastern Queensland (Lake 1971; MacDonald 1978; Llewellyn & MacDonald 1980; Merrick & Schmida 1984). These references cite the occurrence of *M. ambigua* in coastal streams in northern New South Wales, but there are no self-maintaining populations in these drainages (Rowland pers. comm.).

Little is known about the biology and ecology of golden perch larvae and fry in the natural environment. An upstream spawning migration is initiated by water level rises at the onset of major floods (Reynolds 1983). The semi-buoyant eggs are probably carried downstream by the flood waters with the larvae hatching and drifting in the water, before entering shallow floodplain areas and "billabongs", which probably act as nursery grounds (cf. Lake 1967a; Rowland 1983; Rowland pers. comm.). These floodplain areas receive nutrients and allochthonous materials that promote increases in plankton and other organisms essential for survival of the larvae and fry (cf. Shiel 1980; Maher 1984; Briggs *et al.* 1985). In many areas dams and weirs have blocked spawning migrations, lowered water temperatures by discharging colder water from the deeper water layers of dams and reduced flooding which is necessary to induce spawning and provide suitable conditions for the pelagic eggs and space and planktonic food for the young fish (Lake 1971; Reynolds 1976; Cadwallader 1978; Pollard *et al.* 1980; A.R.I.E.R. 1983).

Much of the available information on golden perch larvae and fry comes from research into spawning and larval rearing carried out at the Inland Fisheries Research Station (I.F.R.S.), Narrandera (Lake 1967a, b; Rowland 1983, 1986a, b; Rowland *et al.* 1983). Golden perch are induced to spawn using human chorionic gonadotrophin and the larvae are reared in earthen ponds from first feed until they are about 25 to 30 mm standard length, usually a period of 25 to 35 days. Lake (1967b) observed that the stomach contents of larvae at first feed consisted of cladocerans, copepods and phytoplankton.

The present study was conducted at the I.F.R.S. The main objectives of this study were to describe the growth characteristics of the golden perch larvae in rearing ponds, to investigate the behaviour and ecology of the larvae and fry in relation to feeding, and to measure daily food consumption of the different size larvae and fry. The description of growth involved the determination of length-weight relationships and the estimation of the growth rate of golden perch in a rearing pond. Particular emphasis was placed on the relationship between length and mouth gape, as mouth gape determines the size of prey that can be taken (Shirota 1970). This information, in conjunction with that on feeding behaviour and daily food consumption will provide useful guidelines to the conditions required for survival and growth in golden perch larvae.

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Methods and Materials

Growth Characteristics

Larvae and fry were caught from a rearing pond at I.F.R.S. over a period of 46 days from 12 November–28 December, 1984. They were killed with an overdose of soda water, standard and total lengths were measured, wet weights were determined and then they were dried in an oven for 24 hours at 60°C, and dry weights measured. To establish the power relationships between weight and length, linear regressions were performed on the log transformed data of both lengths and weights (Bagenal & Tesch 1978). For the total length-standard length and dry weight-wet weight relationships, regressions were performed on untransformed data. The growth rates of the larvae and fry in the pond were analysed by establishing standard length-time and dry weight-time relationships. An exponential model gave the best fit and so both standard length and dry weight measurements were log transformed. Mouth gape and standard length were measured for about 450 specimens collected during 1983 and 1984 and preserved with formalin. The mouth gape was measured as the external distance between the two corners of the mouth when shut. The regression of mouth gape and standard length was performed without transformation.

Behaviour

Observations on feeding and territoriality were made on fry from first feed to about 30 mm standard length either alone in 250 ml capacity beakers or in groups of 10–15 in 70 l aquaria. The larvae were fed with brine shrimp (*Artemia*), using the nauplii for the smaller larvae and adults for the larger larvae and fry. Zooplankters and chironomid larvae were occasionally fed to the larvae and fry. Cover was provided in the form of a 30–40 mm length of opaque, plastic tubing with 2.5 mm internal diameter for the smaller larvae and a 60–70 mm length of tube with internal diameter of 3.0 mm for the larger fry (25–30 mm). One cover was provided for the fry held singly and the number of covers was about two-thirds the number of fry for the group study. The study was carried out at 20–24°C under daylight conditions.

Daily food consumption

The daily food consumption of a fish, estimated as the number of food items supplied over 24 hours minus the number of items remaining (cf. Gophen 1980), was estimated for size classes of 4.5 (= first feed), 10, 20 and 30 mm standard length. Freshly hatched brine shrimp nauplii (length: 400–600 μm) were used as food except for the 30 mm fry where *Daphnia carinata* (length: 1600–2320 μm) were used because of the enormous number of brine shrimp nauplii that would have been required. The feeding regime involved small numbers of food items being fed to the larvae and fry at a time, the next feed being given when only a few food items remained. Three to six feeds were required over the 24-hour period. For the feeding trials, five different individuals of a particular size were placed simultaneously in separate beakers which received circulating filtered pond water at 20–22°C. The fry were not starved prior to commencement of feeding trials and a tube was provided as a refuge for the fry. The daily food consumption was expressed as number of items and as μg dry weight consumed per day. Dry weights of brine shrimp nauplii and *Daphnia* were obtained from weighing a known number of oven-dried specimens at 60°C and obtaining the weight per individual brine shrimp nauplius (2.55 μg) or *Daphnia* (20 μg).

Results

Larvae at first feed were 4.4–4.6 mm standard length (mean 4.5 mm) (total length = 4.5–4.7 mm; mean 4.6 mm) with a dry weight of 0.14–0.18 mg (mean 0.16 mg) (wet weight = 0.47–0.58 mg; mean 0.52 mg). Their mouth gape at first feed was 0.5 mm. After 46 days in the rearing pond, they reached 30–31.6 mm (mean 30.6 mm) standard length with a dry weight of 154–195 mg (mean 165 mg) (wet weight = 667–743 mg; mean 691 mg). The regression equations describing length-weight relationships, the relationship between length and mouth gape and the growth rate of fry and their correlation coefficients are given in Table 1. The correlation coefficients of all pairs of relationships are highly significant. In the length weight relationships, regression coefficients (= slopes) ranged from 3.29–3.72 and for this range growth is considered allometric (cf. Bagenal & Tesch 1978). The standard length of the fry was directly proportional to the total length and dry weight was linearly related to wet weight. The exponential growth in both standard length and dry weight are shown in Fig. 1. The growth coefficients for standard length and dry weight were 0.04 mm/mm day and 0.15 mg/mg day respectively (Table 1). The mouth gape of the fry was directly proportional to their standard length with a slope of 0.13 (Fig. 2).

The larvae at first feed swam freely in the water column. They exhibited an innate feeding behaviour of darting forward and gulping even when no food particles were present. After two to three days of feeding, larvae could follow and capture brine shrimp nauplii. Efficiency in capturing *Moina* was lower. When the golden perch were 10 mm and

TABLE 1. *Regression equations, intercepts (a), slopes (b) and correlation coefficients (r) for weight-length, standard length-total length, wet weight-dry weight, mouth gape-standard length, dry weight-time and length-time relationships in golden perch.* (N = number of data pairs; CL – 95% Confidence Interval; P>0.01; DW = dry weight (mg); WW – wet weight (mg); SL = standard length (mm); TL = total length (mm); MG – mouth gape (mm); T – time (days); e – exponential).

Y	X	N	Equation	a	b (+/– 95% CL)	r
DW	SL	29	$Y = a X^b$	7.5×10^{-4}	3.61 (0.10)	0.997***
DW	TL	29	$Y = a X^b$	1.1×10^{-3}	3.29 (0.08)	0.998***
WW	SL	29	$Y = a X^b$	2.9×10^{-3}	3.72 (0.18)	0.993***
WW	TL	29	$Y = a X^b$	3.8×10^{-3}	3.39 (0.13)	0.995***
WW	DW	29	$Y = a + b X$	7.98	4.09 (0.14)	0.996***
SL	TL	29	$Y = a + b X$	0.78	0.79 (0.01)	0.999***
MG	SL	415	$Y = a + b X$	0.23	0.13 (0.10)	0.984***
DW	T	9	$Y = a e^{bx}$	0.22	0.15 (0.10)	0.991***
SL	T	9	$Y = a e^{bx}$	4.81	0.04 (0.0046)	0.992***

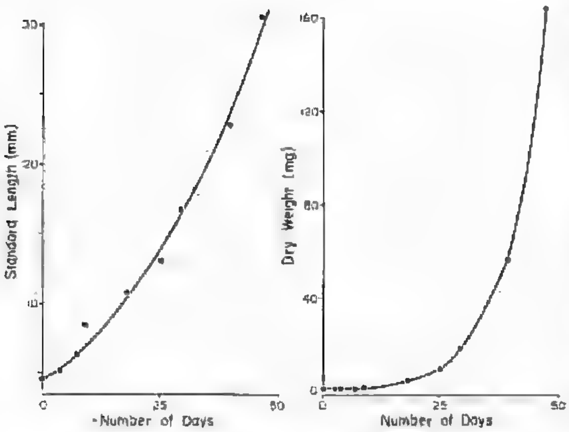

Fig. 1. The growth in length and weight of golden perch larvae and fry from release into the pond on 12 November until harvest on 28 December 1984. The points represent mean values from 3 to 5 fish on each sample date.

greater, they preferred cover when kept alone or in groups and exhibited territoriality. They stayed inside their tube, with part of their head up to the eye level protruding, coming out to feed or to chase other larvae or fry away. When disturbed, they would temporarily retreat inside the tube. When a larger tube was provided, two to three fry sometimes shared it. In group experiments those fry that did not have cover stayed in the water column or at the bottom of the container away from "defined" territories. When food supply was low, the fry in covers were healthier and had more convex bellies than fry without cover, and with continued low food availability mortalities occurred first in fry without cover. Larvae and fry of 10 mm and greater could pursue cladocerans and copepods with ease but the size of prey engulfed was limited by their mouth gape. They attacked very large *Daphnia* but released them as they were too big to swallow. Individuals could slowly engulf a chironomid larva width-wise until the whole larva was swallowed.

The larvae at first feed, ate 7–21 brine shrimp nauplii per day (mean 13), 10 mm larvae ate 240–251 nauplii (mean 247), while 20 mm fry ate 790–1631 nauplii per day (mean 1110). The 30 mm fry ate 141–423 *Daphnia* per day (mean 280). The daily food consumption of larvae and fry ranged from 33–5600 μg dry weight per day and was directly proportional to the standard length of the fish (r 0.899), ($p<0.05\%$) (Fig. 3). There was a large individual variation in daily food consumption as indicated by the spread of the points on the graph.

Discussion

Size at first feed is a critical feature of the biology of larval fish but there is only limited information on the size at first feed of Australian freshwater fish (Table 2). It is clear that golden perch, along with two other large Australian freshwater fish that lay

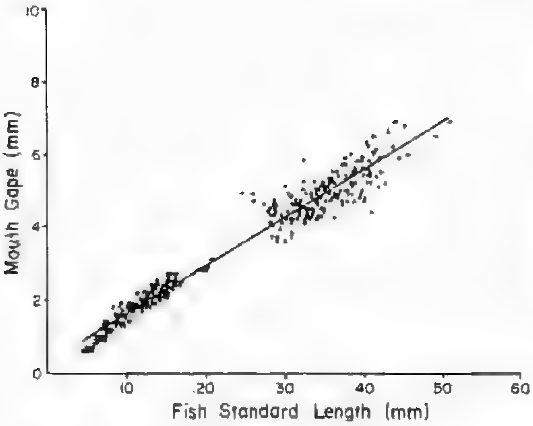

Fig. 2. The relationship between standard length and mouth gape for golden perch larvae and fry from first feed to 50 mm standard length.

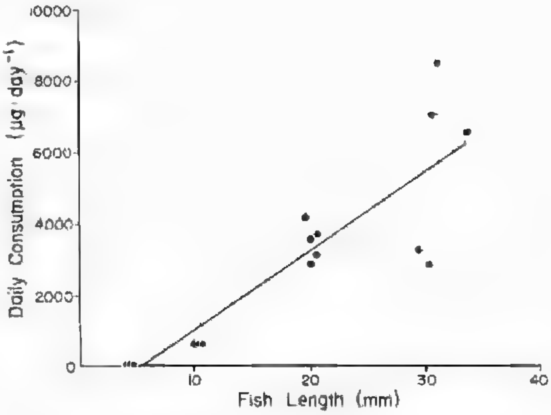

Fig. 3. The daily food consumption (µg dry wt day^{-1}) of golden perch larvae and fry held in the laboratory and fed brine shrimp nauplii or *Daphnia*.

small pelagic eggs, silver perch (*Bidyanus bidyanus*) and silver barramundi (*Lates calcarifer*), possess larvae that are particularly small at the time of first feed. By comparison the larvae of fish such as Murray cod (*Maccullochella peeli*) and freshwater catfish (*Tandanus tandanus*) that lay demersal eggs are up to three times longer than *M. ambigua* larvae, while those of buccal incubating saratoga (*Scleropages leichardti*) and fork tailed catfish (*Arius graeffei*) are up to seven times longer than golden perch larvae at first feed. The small size of the golden perch larvae presents problems for feeding and survival similar to those faced by the larvae of marine fishes during the "critical period" of larval mortality (May 1974). Another percicthyid that breeds in fresh water, the North American striped bass *Morone saxatilis*, has larvae that are only 3.1 mm at hatching and 6–7 mm at the time of first feed and face survival and feeding problems similar to those of golden perch (Doroshov 1970).

The allometric growth form of the fry indicates that golden perch change their body form as they grow. This is consistent with the observation that golden perch fry acquire adult features very early in their development from when the fry are about 11 mm total length (Llewellyn & MacDonald 1980).

TABLE 2. *Total length (TL in mm), size of mouth gape (MG in mm) at first feed and initial food items of the larvae of some Australian fishes.*

Species	TL	MG	Food items	References
Macquaria ambigua	5.5	—	small copepods/cladocerans (<500 microns), algae.	Lake (1967b), Rowland (1986a)
	4.7–4.9	0.5	mainly small *Moina/Daphnia*	This study
Maccullochella peeli	12	—	chironomid larvae, *Daphnia*, copepods	Lake (1967b)
Bidyanus bidyanus	5.5	—	mainly filamentous algae/ phytoplankton	Lake (1967b)
	4.6–5.4	0.4	mainly filamentous algae/rotifers	Arumugam (unpubl.)
Tandanus tandanus	13	—	plankton	Lake (1967b)
Arius graeffei	50–59	—	microcrustaceans, insect larvae, filamentous algae	Rimmer (1985)
Scleropages leichardti	35	—	—	Lake (1971)
Lates calcarifer	3.5–4.5	—	—	Moore (1982)
	—	—	rotifers/algae	M. Mackinnon (pers. comm.)
Cyprinus carpio	6.4	0.55	—	B. Pierce (pers. comm.)
	—	—	small cladocerans/copepods	
Perca fluviatilis	7	—	—	Lake (1967b)
	—	—	algae, ciliates rotifers, cyclopoid nauplii	Guma'a (1978b)

Data from I.F.R.S. shows that metamorphosis from the larva to the fry stage is completed when fish are about 15–18 mm, 20–29 days after spawning (Rowland pers. comm.).

The growth curves for both length and weight of the golden perch in the present study were best described by an exponential relationship with time. The exponential curve also fitted both length-time and weight-time regressions for the first growth stanza of a wild population of *Perca fluviatilis* fry (Guma'a 1978b) but other workers have found that while growth by weight might be exponential, length increases linearly. Thus Swanson & Ward (1985) found that the best fit for total length-time regression curve for walleye (*Stizostedion vitreum vitreum*) was achieved with untransformed data and A.R.I.E.R. (1983) assumed linear length-time relationships for common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and redfin. However in these studies, the sampling intervals were so far apart, especially in the earlier larval phase, that any possible exponential relationship during the early growth phase would have been obscured. The exponential rate of growth of golden perch larvae and fry (0.15 mg mg^{-1} day^{-1}) can be compared to the growth rate of fish fry and juveniles, expressed as % increase in weight per day, reviewed by Brett (1979). Growth rates varied from less than 1% to as high as 23% for small (5 mm) *Cyprinodon macularis*. Most figures for various fish under good conditions were between 1 and 5%. The value of 15% for golden perch in the present study represents relatively a high rate of exponential growth. This is not surprising as the golden perch were very small and were in a pond that was fertilized and managed to promote maximum survival and growth.

The mouth gape of the larvae at first feed is important because it determines the size of food items that can be taken during this critical period. Shirota (1970) showed that mouth size of marine fish larvae at first feed ranged from 200 to 1000 µm and that the range of prey was related to mouth size. In many fish, the size of prey eaten has been shown to change with growth and the associated increase in mouth gape (Shelbourne 1962; Einsele 1965; Shirota 1970; Wong & Ward 1972; Siefert 1972; Guma'a 1978a; Townsend 1983). Therefore comparisons between the mouth gapes of different length golden perch larvae and fry and the array of common zooplankters in the rearing ponds will indicate the food items that can be taken by different sized fish (Fig. 4). The larvae at first feed are smaller than large *Daphnia carinata* and chironomid larvae. Their mouth gapes are similar to or larger than the smallest *Daphnia*, small *Moina*, copepodites, cyclopoids, copepod nauplii

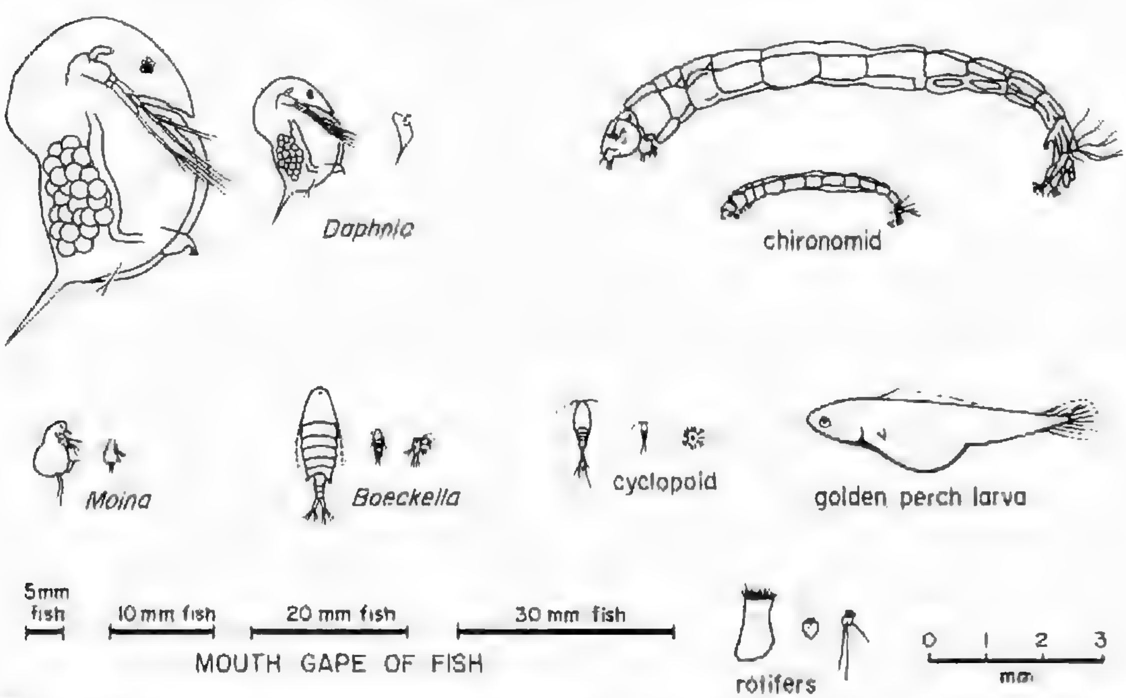

Fig. 4. Relative sizes of the development stages of some common zooplankters and insect larvae in the fry rearing pond, golden perch larva at first feed, and the mouth gapes of golden perch larvae and fry of different standard lengths.

and rotifers, making them all potential prey. The potential prey size increases as the fry grow. At 30 mm standard lengh, the mouth gape of golden perch is similar to or larger than the largest *Daphnia* available in the plankton.

The observations on feeding behaviour suggest that golden perch larvae at first feed would have a relatively poor capture efficiency. For striped bass at first feed the estimated strike efficiency on *Artemia* nauplii was only about 2% (Miller 1977 in Setzler *et al.* 1980). More mobile zooplankters would be less prone to being captured. Cladocerans are more sluggish and more conspicuous than other zooplankters such as copepods and would be more prone to being eaten by the larvae (Zaret 1980). The feeding efficiency of the golden perch larvae improved very rapidly and after 2 to 3 days they were able to follow slow-moving brine shrimp nauplii and capture them with ease. At 10 mm, they were agile and fast enough to attack any cladocerans, copepods, or chironomid larvae. Being a faster swimmer with good escape responses (Zaret 1972) would not be an effective strategy for a prey at this stage. The speed and agility of the fry meant that once they visually sighted their prey, capture was inevitable. In fact, zooplankton that are faster swimmers and cover a greater distance (e.g. copepods) may become more prone to being predated because the probability of encountering the fish would be greater (Townsend 1983).

Although there was a high correlation between daily food consumption and standard length of the fry, variability of daily food consumption for the larger fry was high. Fry used in feeding trials were individuals recently caught from the pond and so different growth histories and different levels of satiation may have contributed to high variability (Elliott & Persson 1978). Also, the larger fry were easily disturbed and this may have affected feeding. Considering that the food intake increased as a linear function of size and that growth of golden perch in the pond was exponential with time, the daily food consumption would also increase exponentially with time. Thus the intensity of predation by the fry on the zooplankton populations would increase slowly at first but at later stages it would increase rapidly and might produce a sudden impact on the zooplankton community.

The information on feeding behaviour, growth and the mouth gape, highlight the difficulties faced by golden perch larvae and fry. Survival and growth requires an environment with a high density of appropriate sized food so that larvae with limited feeding ability and mouth gape can predate successfully. Mouth gape increases only slowly during the first weeks and so the range of zooplankters available to the fry will be limited for some time and high densities of small (<1 mm) zooplankters will be necessary for high survival and growth rates. These requirements are met at the I.F.R.S. where ponds are flooded just prior to the release of fish fry and the early stages of zooplankton succession are dominated by rotifers, small cladocerans (especially *Moina*) and copepod nauplii (Arumugam & Geddes 1986). In the wild, the same conditions may be provided in recently inundated floodplain areas where zooplankton communities are in early successional stages. If so, then the possession of pelagic eggs and the timing of breeding to coincide with rising water levels may allow golden perch larvae to be dispersed over recently inundated floodplains where they find conditions that are suitable for their development. The availability of cover for the fry in these areas may also affect the growth and survival.

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